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MORPHOLOGY AND BIOLOGY OF SIMULIUM VITTATUM AND ITS DISTRIBUTION IN KANSAS, ... *W. T. Emery.*

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THE KANSAS UNIVERSITY SCIENCE BULLETIN.

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The Morphology and Biology of *Simulium vittatum*

AND ITS DISTRIBUTION IN KANSAS.

BY W. T. EMERY.

Plates XXXVIII to XLII.

Submitted in partial fulfillment of the requirements for the degree of master of arts.

PREFACE.

THE following paper was written from the data and material collected as a result of a request from Governor Stubbs of Kansas, 1911, through the State Board of Health, and Dr. S. J. Crumbine, dean of the school of medicine, and Prof. S. J. Hunter, professor of entomology, at Kansas University, to locate sand flies (*Simulium*) in their geographical location to pellagra cases in the state.

Here I wish to thank Prof. S. J. Hunter for his kind assistance in conducting the investigations, and for his many helpful suggestions in working out the problems, both in the field and in the laboratory. We are indebted to Dr. O. A. Johannsen for determining the species *Simulium vittatum*. Mr. H. B. Hungerford was kind in helping me secure literature on *Simulium*. I also appreciate the assistance of Messrs. F. X. Williams, A. E. Mallory, E. C. O'Roke and H. R. Jennings of the Kansas Biological Survey of 1911, for collecting specimens of *Simulium* and observing their habits and breeding places. I thank Dr. Grace M. Charles of Kansas University botany department for determining the algæ in the alimentary canal of *Simulium* larvæ. Mr. L. M. Peace made the photographs of the *Simulium* figures used in the text.

Morphology and Biology of Simulium vittatum and its Distribution in Kansas.

On casual observation *Simulium* flies are about the size of the common fungus gnats (Mycetophilidæ) which we often see on a piece of apple peeling or on decaying fruit. However, upon closer examination they are found to be distinctly different both in form and color. These little flies are gray to black in color and are from two to four millimeters in length, depending on the species and sex. They have a conspicuously prominent thorax, hump-backed in appearance, and their heads are drawn down in front of them. This latter characteristic adds to the prominence of their thorax, so much so that they have received the popular name of buffalo gnats. In the South they are called turkey gnats, in the North black flies, and in Europe sand flies.

Perhaps the most conspicuous characteristics of *Simulium* flies are their comparatively heavy cone-shaped antennæ that protrude from between the eyes at the base, diverging like a pair of horns. They are about the length of the head, ten jointed, with the joints closely articulated except the two basal ones, which are differentiated. Other noticeable characteristics are their relatively broad and slightly veined wings, their prominent thorax, and the structure of their mouth parts.

The latter to be seen well must be dissected and placed under a compound microscope. These I shall describe further on in the paper. At the time of emergence their eyes have a reddish tinge. They have no ocelli. Compared with other flies of their size the legs are thick and heavy set.

LIFE HISTORY—HABITAT.

Nearly every one has observed mosquito wigglers in rain barrels and pools of standing water, but unlike this habit of mosquitoes, *Simulium* flies breed only in running water, such as ripples and waterfalls. It seems that its aquatic larval nature demands well aërated water if it is going to live and complete its life cycle. For instance, if a *Simulium* larva is placed in a vessel of standing water it soon dies, apparently for the want of sufficient oxygen. When *S. vittatum* is washed from the rocks in shallow ripples into deep water it will drown, unless it floats with the current to another ripple or waterfall where it can attach itself to a stone or vegetation.

As a rule, in regions where *S. vittatum* occurs the larvæ are found in the ripples and falls of creeks and small streams, not rivers, that flow the year round. The most essential condition for the well-being of these aquatic creatures is rapid motion of the water in which they live. Not only did the writer find this to be the condition, but in the Kansas Biological Survey notes for 1912, Mr. E. C. O'Roke writes, at Hays City: "While scouting about for a camping place we observed larvæ and pupæ of sand flies on a concrete dam and on the rocks below it in Big creek." In another part of the notes Mr. A. E. Mallory, at Rush Center, says: "We found many *Simulium* larvæ and pupæ in the ripples." In the same field notes Mr. F. X. Williams, at Ness City, writes: "In a small branch of Walnut creek, where the ripples are weak and the bottom is pebbly, but with no stones, I found *Simulium* larvæ, pupæ and eggs plentiful on the sedges lying flat in the ripple." This last note shows that while there were no stones to break the flow of the water, yet the sedges, on which the *Simulium* lived, were washed by the current.

As to the character of the water in their breeding places, it is generally clear and well aërated, though sometimes it contains considerable organic matter. Two of the breeding places observed in Kansas where the flies were very numerous were streams that carried sewage. One was at Rosedale, Kan., a suburb of Kansas City, and the other was at Oswego, Kan. Doctor Forbes, of Illinois University, states, in his report on *Simulium* of that state, that the larvæ were found in the sewage drains far up into the city of Chicago.

Since their habitat is in ripples or in places where the water is accelerated by an obstruction, it is interesting to observe what takes place in standing water. Our observations in the laboratory showed that they died in about an hour; at least they would not respond to stimulation after that time in a vessel of water. Consequently, in a stream when the larvæ are swept into quietly running water, they drown unless they can maintain themselves in the current long enough to float to another ripple. In a little stream near Oswego, in which there were two ripples about fifty yards apart, the second ripple or the one below was narrowed so I could observe approximately the number of larvæ on the stones. After disturbing about fifty or more larvæ in the upstream ripple,

causing them to let go their holds on the rocks and drift into the quiet slow-running water, I was unable to detect any increase in the number of larvæ in the small narrow ripple below. However, after a rain which caused a swifter current between the ripples, I could sometimes find more larvæ than usual in the lower ripple. Ordinarily the current was sluggish between the ripples.

From our observations, there are three principal broods of *S. vittatum* each year. One occurs in early spring, the fore part of April; one in mid-summer, from the middle to the latter part of July; and one in mid-autumn, the latter part of October, the time for these broods varying with the earliness or lateness of the seasons. The general time for the spring and fall broods seems to be at the heavy frost-line period. This period varies with different species and in different states.

Mr. Otto Lugger, the state entomologist of Minnesota, in his report of 1896, pages 201 and 203, says in part on *Simulius* flies: "The first species seen and felt occurs early in the spring soon after the snow disappears. This species (name not given) flies from May 13 to June 1. A little later in the season, but chiefly during June and July, a somewhat larger species, *S. decorum* Walker (synonymous with *vittatum* Zetterstedt, according to Coquillett) becomes numerous." Mr. C. V. Riley, in the report of the United States Entomologist for 1886, pages 342 and 343, refers to Mrs. Sara J. McBride, of Mumford, N. Y., as stating in one of her articles that "the perfect flies issued about April 1st." In the *American Journal of Science*, volume I, 1913, under the heading, "A Destructive Insect," mention is made that, "Contrary to the custom of other insects, it (*S. pecuarum*) always appears when cold weather commences in December, and as invariably disappears on the approach of warm weather, which is about April 1 (Choctaw county, Mississippi), and continued to return at the same season from year to year."

In the report of the Commissioners of Agriculture for 1886, Entomologist C. V. Riley says, in speaking of the southern buffalo gnat (*S. pecuarum*), as to its time of appearance: "The first swarms were observed last year in Louisiana on March 11, in Mississippi and Tennessee May 1, and in Indiana and Illinois May 12. Small local swarms may appear somewhat earlier or later in the neighborhood of their breeding

places. The turkey gnat (*S. meriodionale* Riley) appears usually later, although in 1886 it appeared near Memphis, Tenn., as early as April 5. The swarms were quite local, however, and strictly confined to the vicinity of the creeks that produced them. The greater majority of the species of this genus are northern insects, and appear there in the winged form all through the summer. The larvæ require cold water for development. As we go farther south the cold water can only be found in the more elevated regions or in winter or in the earlier months of spring. Earliness of season or high altitude are the substitutes for the lower temperature of the more northern latitude." All this goes to show that the time of the appearance of *Simulium* broods varies with different species and in different states.

That *S. vittatum* emerges throughout the summer is shown from my field notes on that species in our experiments to determine whether or not it is capable of transmitting the disease pellagra. We collected pupæ as they formed on the rocks, and placed them under a trap which was over the ripples so as to secure as many flies as possible (fig. 1). The following dates show uneven emergence of the flies from the breeding traps and how they increase in numbers as cooler weather approaches, until the creek freezes:

OSWEGO, KAN., 1911.

Date.	No. flies.	Temperature, F. Mx.	Mn.
Sep. 7	2	84	65
8	5	83	68
9	3	83	67
10	5	89	68
11	6	91	70
13	24	94	73
14	4	92	73
19	6	73	57
20	17	71	58
21	11	74	52
22	9	82	53
24	6	89	67
25	4	90	68
27	10	90	68
28	9	91	70
29	16	81	70
30	6	83	61

Oct. 2	70	90	65
3	70	88	71
4	100	78	58
5	150	84	60
6	120	83	62
7	54	63	51
8	150	65	48
9	105	61	50
10	60	69	43
11	40	81	54
14	108	85	57
16	40	77	46
17	56	71	43
18	22	73	45
20	4	55	40
23	25	68	30
24	5	69	37
25	12	67	45
26	12	73	36
30	2	53	34

February 15, 1912, Rosedale, Kan.—Full-grown *Simulium vittatum* larvæ covered the under sides of the rocks in the ripples in Turkey creek where it enters the city.

June 7, 1912, Rosedale, Kan.—*Simulium* larvæ were less numerous and smaller than those observed February 15. This is a good evidence that a brood must have come off early in the spring, leaving these stragglers to emerge later. Some of these later larvæ I placed in a ripple in the laboratory at Kansas University, getting them to pupate and emerge later. From a few pupæ that I brought to the laboratory at that time eight flies emerged on June 8. From the larvæ that pupated in the laboratory twenty-four flies emerged June 19.

Of the midsummer *S. vittatum* brood that emerged from a small stream on the University campus the following dates and number of flies taken were accounted for:

Jul. 13	40	flies.
16	15	"
21	2	"
22	1	"
25	3	"
27	3	"
28	5	"
29	4	"
Aug. 4	2	"
5	2	"
7	2	"

Observations on *Simulium* could not be carried through the summer at Rosedale nor at Oswego because the streams at those places dried up during the drouth, and as a consequence the *Simulium* there ceased to propagate themselves.

The following number of *Simulium* flies were trapped in the Little Arkansas river at Wichita, Kan.:

Nov.	10	12 flies.
	11	5 "
	12	33 "
	13	20 "

Simulium flies may emerge during a warm spell in the winter, as our experiments in December, 1912, show. My field notes read as follows: "Dec. 11, Wichita, Kan.—Took 50 to 60 *S.* pupæ from partly frozen river and placed them in a laboratory, using city water. Dec. 12.—14 *S.* flies emerged. Dec. 13.—10 *S.* flies emerged."

A moderate or cool temperature seems to affect not only the length of an individual *S. vittatum* fly's life, but also its biting habits or blood-thirsty nature. "If cold weather follows their appearance, the gnats become semidormant; they are not killed by it nor by rain, but revive and become aggressive again with the first rays of the sun. Hot weather, however, soon kills them."[1]

During the months of September and October, 1911, we used over 1200 flies in our experiments with pellagra. Not until the cooler weather, the later part of October, did we succeed in getting the flies to bite. At this time the temperature was about 20° cooler than when they had refused to bite. According to the local U. S. government weather station, the temperature frequently ran above 90° in September, with an average maximum of 86.1° and minimum of 65.7°, while in October, at the time of biting, the maximum was 67° and the minimum was 45° F. Again in the middle of November the following year, 1912, I caught *S. vittatum* at Wichita, carried them over 150 miles to Topeka, and succeeded in getting them to bite. One month later I took *Simulium* pupæ from the Little Arkansas river, which was partly frozen over, placed them in a laboratory with water running over them at a temperature of 60° F., and secured twenty-four flies. They were then taken about 200 miles to Parsons, where we succeeded in getting four of them to bite a supposed case of pellagra. (Only sixteen flies, one-half of which were males, made the trip).

Before this time I had supposed that perhaps the flies had to oviposit before they would bite, but from the above experi-

1. Dept. Agri. 1886.

ments it appears to be a matter of stirring them to that activity by the proper temperature during their life cycle. At no time have I been able to find eggs deposited on the rocks underneath the traps where the flies emerged that did the biting. Literature on the subject of their habits of biting refers to them as being the worst to bite in early spring and late fall, in the early morning and on cold rainy days. The argument in the U. S. Department of Agriculture Year Book, 1886, quoted in bulletin 5, 1896, is that *Simulium* flies oviposit before going out in swarms to seek warm-blooded animals, that when once gorged with blood they soon die, and that microscopical examinations have failed to reveal any eggs in the ovaries composing these swarms, therefore they evidently oviposit before biting.

Our experiments brought out the fact that *Simulium* will bite in captivity and in houses, also that they can be shipped long distances and kept alive for two and three days without feeding. As for keeping *Simulium* alive in captivity, the males died soonest, living one to two days, while the females would live two to four days. When filled with blood (human) we kept one female alive seven and one-half days, from Friday afternoon of one week until Friday morning of the following week, at which time the fly was destroyed in our experiments. Just how long they can be kept alive by refeeding I do not know. They are said to feed on maggots and caterpillars. (British Diptera, p. 165.)

It is interesting to watch the flies oviposit on the stones in ripples. The female selects a stone in the ripple where a film of water seeps upon the lower downstream side in very small vibratory waves. In these tiny waves she places the tip of her abdomen and wings and deposits from 200 to 300 eggs strung back and forth as she moves along, in rows close together so as to form a mass, usually from one-fourth to three-eighths of an inch long and from one-sixteenth to one-eighth of an inch wide. Here the waves constantly wash the tip of the abdomen and afterwards keep the egg mass moist. From five to ten minutes is spent in the process. In midstream, where the current made the small waves best, several egg masses were piled upon one another and alongside adjoining, sometimes covering the whole downstream side of the rocks. Frequently a fly would cease ovipositing and go away to finish on another rock or perhaps to return to finish on the same rock.

Some of the eggs were laid on old leaves in the ripple. N. Y. St. Mus. Bul. 47, p. 408, gives the following on oviposition: "The place selected is always at the edge of a little waterfall, on a surface that is intermittently washed by the swaying current, and so kept wet. Here the females flock and pile up great white masses of eggs, which with a little age turn yellowish. Waves dash over them while ovipositing, and often sweep them away, but they at once return to their task."

The description of an egg mass is given in my field notes for October, 1911, as follows: "*Simulium* eggs when first deposited are whitish or creamy in color. In two or three days they begin to turn yellowish, becoming later a rusty yellow, then brownish to a dark brown, almost black at time for hatching. All this time they retain a shiny appearance. The empty shells after the larvæ have hatched look dull, tattered, torn, and sunken in, soon breaking to pieces in the rippling water. When first hatched a larva is so small and light in color that one can hardly see it on a rock with the unaided eye. On account of the reflections of a wet rock it is even difficult to see with a 12× lens if the larva is not moving."

A variation in the length of the incubation period is shown in my field notes. "October 26, 1911.—Discovered very small larvæ, 1 mm. long, on rock with egg mass that I found October 19. Yesterday the eggs were full; to-day many of them were sunken in. October 28.—Found more small larvæ on rock with eggs discovered October 19. October 30.—Part of the eggs laid on the rock that I placed in the ripple for that purpose October 23 are rusty yellow and very shiny. November 2.—Creek partly frozen over. Eggs of October 23 apparently still unhatched, but covered with a dirty slime like empty shells. Part of them were hatched, though I could find no young larvæ with them.

The dates from October 19 to 26 show a period of eight days, while that from October 23 to November 2 shows a period of eleven days for incubation. That variation is due, no doubt, to the decrease in seasonal temperature to freezing.

Now the length of the larval stage may also vary. Taking the periods between the broods previously mentioned—that is, from the fore part of April to the middle of July, and from mid-July to the latter part of October—we find the length of life cycle during the warmer months to be approximately three months and one week. Allowing five to six days for the

length of the pupal stage, as we observed it in September, 1911, and eight days for the incubation of the eggs, we get the length of the larval stage in the warmer months to be about two months and three weeks. For the life cycle of the spring brood, that leaves a period from the latter part of October to the first part of April, or about five and one-half months. Since it is in the larval stage that they winter over, it would indicate that the winter temperature prolongs the length of the larval stage for the spring brood.

Newly hatched larvæ are a pale creamy color, and about one millimeter in length. They possess indications of the same general characteristics of form and structure that the full-grown larvæ have. The color soon darkens to a slaty green.

A full-grown *S. vittatum* larva measures from five-sixteenths to three-eighths of an inch in length. The body is somewhat attenuated in the second abdominal segment and gradually increases in size in the third, fourth, fifth and sixth segments. Beginning with the seventh segment there is a much increased or abrupt expansion that gives the larva a widened and flattened appearance.

The metathoracic and mesothoracic segments and the first six abdominal segments are cylindrical. The prothoracic is thickened dorso-ventrally by the attachment of the single prothoracic leg. (Plate XXXIX, fig. 11.) The head is semi-flattened, with a slightly constricted neck, and is about the length of the thorax.

On the head are some very unusual prehensile organs, used to collect food from the rippling water. They are fan-like in shape, with forty filaments or rays in *S. vittatum*. (Pl. XLI, fig. 31.) When disturbed, or when the larva is taking food from the rays with its mandibles and maxillæ into the mouth, the fan is closed so that the tips of the rays come just to the oral opening. These rays are scythe-shaped, ciliate on the inner side, with longer setæ at regular intervals. (Pl. XLI, fig. 31.) The rest of the mouth parts, labrum, mandibles, maxillæ, hypopharynx and labium, together with the antennæ, are shown individually and compositely arranged on plate XLI, figures 32-35. Between the fans are the slender five-jointed antennæ; the fifth joint is a pointed process at the end of the fourth. Back of the fans on each side of the head are two narrowly separated black spots. These may be eyes, or light organs. Besides the leg or foot, on the sides of the

thorax there appears on the full-grown larva black spots which are the pupal gills, folded and drawn up beneath the skin.

At the caudal end is a sucker-like aperture used to hold the larvæ to the stones and debris in the ripples. It is made up of a series of rows of tiny hooks. On the dorsal side the sucker-like organ is produced into a V-shape. (Pl. XLI, fig. 35A.) Cephalad of this are the breathing gills. In *vittatum* these are three-branched, as membranous sacs, finger-like, when the larva is undisturbed in the water.

In preserved specimens the gills can not be seen unless forced to distend by pressure from a dissecting needle placed cephalad of them.

The larvæ intermediate in size appear to seek the swifter ripples, while those about ready to pupate and the smaller ones seek the less violently agitated parts of the ripples. When moving about on the stones they have a looping motion, similar to that of a geometrid larva. They more frequently make their looping motion laterally instead of dorsally. In doing this they first attach their thoracic leg, then draw their caudal sucker forward and attach it. Frequently one can see the silken thread they spin as they move about. It looks as though they always kept the thread attached, because at any time they are washed from the stones or debris they will float away from one to ten inches, holding fast to the thread, which they spin as they go.

The larva possesses two silk glands, laterally placed, extending about three-fourths the length of the body, then recurved, U-shaped, extending back to the thoracic segments. The outlets are the two ducts which lead into the hypopharynx.[2] Besides being used as a means of security, the thread is used to float out in the ripple while feeding, and for building the pupa case. Ordinarily, while feeding, the larvæ attach their caudal sucker to the object in the ripple and let the rest of their body and head float at an angle of sixty to ninety degrees. I have watched them in the water draw their fans in and scrape them with their mandibles as though collecting food.

With the kind assistance of Dr. Grace M. Charles, of Kansas University, we found several species of diatoms and the following kinds of algæ in the digestive tract, which I take to be the food of *S. vittatum: Conferva, Scendesmus, Chlanydomo-*

2. N. Y. St. Mus. Bul. 68.

nas, Engrena, and *Charcium.* Besides these I found several kinds of bacteria in a smear made from the alimentary tract of a *Simulium* larva.

"According to the unpublished observations of Miss R. Phillips (of the class of 1890, Cornell University) the larva feeds on algæ, as *Nothix, Chaldophora, Vaucheria,* on diatoms, and parts of phanerogamous plants. Sand also has been found in the digestive canal." (N. Y. St. Mus. Bul. 68.) "A searching investigation of the water in their breeding places revealed the fact that it was swarming with animal life and was filled wih the larval forms of small crustaceans belonging to various families, but chiefly to those of copepods and isopods. Larvæ of the southern buffalo gnat (*pecuarum*) kept in glasses were observed to swallow these minute crustaceans, and none of this food was seen to be expelled again. A number of square diatoms, jointed together in a chain, have also been observed by the aid of the microscope." (U. S. Dept. Agri. Yr. Bk., 1886, quoted in Bul. 5, n. s.) The above would indicate that *Simulium* larvæ are both herbivorous and carnivorous.

A very interesting part of *Simulium* larvæ's and pupæ's habits was learned when we discovered their ability to keep alive in a wet pack of cloth or snow for several hours. Our first experiment with that was on February 15, 1912, when I packed some *Simulium* larvæ, on the rocks, in wet snow wrapped in cheese cloth. The time of packing was 5 P. M., the place Rosedale, Kan. From there I transported the mass in an old suitcase to Lawrence and placed them in a ripple in the laboratory at 8 P. M. The snow pack was frozen when I unpacked the larvæ, but they were active and continued to live afterward in the laboratory.

The next time we tried that experiment was June 7, 1912, when I packed the larvæ and pupæ on rocks in wet cheese cloth at Rosedale at 5 P. M., brought them to Lawrence and placed them in the laboratory ripple alive at 11 P. M. Some of the larvæ left in the wet cloth were still alive at 10 A. M. the next day, June 8. This made a total of seventeen hours that the larvæ kept alive in the wet pack. The pupæ continued to live, so that imagoes emerged June 14. The larvæ soon transformed to pupæ, and twenty-four flies emerged June 19.

Again on August 3, 1912, I brought to Lawrence from Rosedale several pupæ torn from the rocks and several larvæ off the rocks in a wet pack in a tin box. Those larvæ lived

through that ordeal all right, and two flies emerged from the pupæ August 4. However, at this time the Lawrence city water was so impure that they were using strong chemicals to purify it. This seemed to kill the larvæ, so that they were all gone from the ripple August 5. No more flies emerged from the pupæ. Larvæ newly hatched from the eggs in the laboratory ripple soon died. On July 2, I placed *Simulium* eggs in the laboratory ripple, and on the 5th and 7th I found newly hatched larvæ, but the city water seemed to kill them after hatching; at least they disappeared.

Our experiments had been so badly interfered with in the laboratory by drugged water, and the several streams in the state where we were conducting experiments went dry during the drouth of the summer, so that our experiments looked dubious. Fortunately I located a good brood of larvæ in the Little Arkansas river at Wichita. Knowing that *Simulium* breed in sewer ditches, and desiring to establish a permanent brood near our laboratory, I decided to take a number of the larvæ from the stream at Wichita and place them in the sewer exit, in good ripples and a fall, at Lawrence where it empties into the Kaw river. On October 8 I collected several hundred nearly grown larvæ, from 4 to 5:30 P. M., transported them in a wet pack off the rocks to Lawrence, where I placed them alive in the sewer at 7:15 A. M. October 9. October 10 a lot of the larvæ had disappeared. October 11 most of the larvæ had disappeared. A piece of cloth that I had left in the sewer with larvæ on it smelled strongly of kerosene and had a white sediment on it. The rest of the larva soon disappeared. Since that time I have succeeded in keeping a *Simulium* larvæ alive in a tin box with a wet cloth for more than seventy-two hours.

Simulium pupæ, when first formed, are a yellowish brown color, later becoming darker as the dirt in the water discolors them and as the imago develops within the case. With the filamentary breathing gills a pupa measures about one-eighth of an inch long. (Pl. XXXIX, fig. 7.) Their gills or respiratory filaments arise from a common base on each side. In *S. vittatum* the base of one gill divides into two, and from each of these arise four branches, these again each dividing into two, making sixteen tracheal filaments for each gill.

According to observations made by Miss Phillips and recorded in her thesis, 1890, the spinning of the cocoon of

S. pictipes is described as follows: "In spinning, the thread issues from the mouth and is placed in the different positions by the thoracic proleg. The head is bent down, and with the proleg the thread is drawn around the body, except the head. The skin of the head is then cast off, and the insect then pulls itself out of the skin of the body, leaving it whole. The cast skin may often be found in the cocoon with the pupæ. The cocoons are commenced at the upper margin and spun continuously down to the caudal end, where several threads are drawn from the cocoon and attached to the last one or two of the body segments of the pupæ. The threads hold the pupa very firmly and are always found when the pupa is pulled out of its case.[3]

I found it very difficult to watch *vittatum* spin their cocoons, because the adult larvæ almost invariably go to the under side of the rocks and debris or seek a protected place in the ripples for pupating. *Vittatum* pupæ are, when first formed, drawn back into their cases so that only the pupal gills show from a dorsal view. Inside of a day or two they begin to push out a little, showing the head bent down and the origin of the gills. On the fifth day after pupating I observed some pupæ that had swung free from their cases and faced in the opposite direction alongside of them.

They were still attached by two threads that ran into the pupæ cases. A description of the same habit of slipping from their cases is given in the United States Department of Agriculture Year Book, 1886, p. 508. We observed a pupa in a vessel of water turn over in its case. It was seen to do this several times, always turning on its ventral side.

When the pupa is drawn from its case, upon close examination one can see two small black blunt hooks on the dorsocaudal end of the pupa, and eight similar hooks on the dorsal front marginal side of the abdominal segments, four in a row on each side, parallel to the margin of the segments; they are a part of a membranous covering as shown in plate XXXIX, figure 9. By means of them it attaches itself to the silky threads of the pupa case.

A general external view of the individual pupa on a rock is shown in plate XXXIX, figure 7. One can see the origin of the pupal gills, and the head tucked beneath, also the prom-

3. N. Y. St. Mus. Bul. 68.

inence of the thorax within the case. Plate XXXIX, figure 7, shows a pupa with the imago within more developed and its habit of withdrawing from the case as it matures. Plate XXXIX, figure 8, shows a newly formed pupa removed from its case. This shows the wing pads in their early development. Plate XXXIX, figures 7 and 9, show lateral and dorsal views with the wing pads more developed.

Emergence of the Adult.

It is very interesting to watch the fly emerge from its pupal skin. The skin is split longitudinally on the fore part of the hump of the pupa. First the fly gets its head and fore legs out, then by pulling itself forward it gets the middle legs and part of the wings out, continues to crawl forward, freeing its wings, hind legs, and abdomen. The whole process took about five seconds on a stone that I held in my hand out of the water. It left the old pupal skin fast in the case with the respiratory filaments intact.

Empty skins soon wash out of the their cases, which are left as little tough empty pockets to fill with dirt and eventually be washed away.

Mr. E. C. O'Roke, in his field notes of the Entomological Survey, 1912, writes the following about newly emerged *Simulium:* "They would dry their wings about five seconds, then fly." He watched them emerge from a board which he held out of the water. On the same survey Mr. F. X. Williams notes: "Almost immediately on reaching the surface (of the water) the fly (*S. vittatum*) would make efforts to rise on its still flexible wings; sometimes, being unable to do so immediately, would skim along the water for a way." His notes continued to say that unless they arose after skimming and floating around a short time they were devoured by some small fishes a few feet below the place of emergence. Mr. H. R. Jennings, on the same survey, notes: "The adult fly would first show up on the surface of the water, having emerged from a pupa case among the spirogyra, and then passed to a place free enough from spirogyra to allow it to come to the surface. Once at the surface, the fly would float on down the stream until it caught on the spirogyra, and was there able to wait until its wings were thoroughly ready before attempting flight, or, if carried by the current into a place free of spirogyra or other surface obstructions, the fly would, when permitted to float upon the surface

of the water, wait until ready for flight." This shows that the flies do not take flight immediately after emerging from their pupæ, either when in the open air or when emerging beneath the water. Instead, they wait a short time for their wings to dry and harden.

Predaceous Enemies of Simulium.

Like most insects, *Simulium* flies have their predaceous enemies, and may have some parasitic ones, though little is known of the latter. U. S. Dept. Agri. Bul. 5, n. s., 1896, gives an account of some of the natural enemies of buffalo gnats, as follows: "But few birds have been observed to feed upon them, though for the southern forms, the mockingbird, winter wren, and especially barnyard fowls, after the flies become gorged with blood, feed upon them. Dragon flies (Libellulidæ) and robber flies (Asilidæ) have been observed to catch them. The larvæ are devoured in large numbers by the smaller fishes, minnows, etc., and probably the carnivorous beetles, bugs, and other aquatic insects prey upon them."

Perhaps the best observations of predacious enemies of *Simulium* larvæ, says in part: "I observed some small carabid by Messrs. E. C. O'Roke and H. R. Jennings on their Entomological Survey of 1912. Mr. O'Roke, in writing about *Simulium* larvæ, says in part: "I observed some small carabid beetles, the kind you see along mud on stream banks all over this section of country (Ellis county), feeding on the sand-fly larvæ. Two would take hold of a small larvæ and pull it much like two chickens pull an earthworm. This was after I had removed the larvæ from the water on a stone."

Mr. Jennings, in writing of the chances a sand fly has of getting away from the water upon emerging from their pupæ where fish exist, says in part: "Any fly unfortunate enough to remain on the surface until the water was deep enough for fish, and also free from algæ, was very certain of having an immediate and fishy grave. Repeatedly I saw flies disappear from the surface in this manner, and to make sure that it was not by flight, I crippled some of them and took care that they floated within reach of the fish, when their disappearance was both immediate and certain. In fact, very few flies which got into the current were allowed to leave the surface of the water in flight, and these few probably owed their existence to the fact that a strong wind was blowing directly upstream, and

hence against the current. This would frequently delay the downstream journey of the fly, and occasionally long enough for safety."

Mr. Williams said he saw a hydrobatid suck the life blood out of a fly. Here we have fish and beetles preying upon the adults and larvæ.

METHODS OF CATCHING AND HANDLING SIMULIUM FLIES.

Trapping *Simulium* flies is an interesting proposition from the nature of their habits and habitat. Ordinarily we can catch a great many kinds of insects with a net. In the case of *Simulium* flies, unless they are in swarms or are very numerous over the water, it is difficult to get many of them that way.

In order to carry on our experiments it was necessary to have them alive and in large numbers. Swarms of them were not to be found, and only a very few individuals were hovering over the ripples at any time. We at once decided to trap them in the ripples as they emerged from their pupæ, and thereby secure flies free from any contagion that might interfere with our experiments.

On account of the habits of the pupæ requiring simply moisture to keep their gills wet, I had good success getting the flies to emerge by placing stones with pupæ on them in straight running water, and then setting a trap over them. The trap consisted of a small wooden box about one foot deep, one and one-half feet wide, and two feet long, without a top. This was turned bottom side up and a hole eight inches in diameter cut in it. In this hole I tacked a cone made out of window screening covered with cheese cloth. Then by cutting notches in the ends of the box to let the water run through without leaving a hole for the flies to crawl out, the trap was complete. The box being dark inside, the flies upon emerging came up into the light in the cone and rested on the inside of it. Plate XXXVIII, figure 3, shows the structure of such a trap.

At first I tried the screening alone without covering it with cloth, but the flies crawled through the meshes and escaped. Another thing I tried was a small screen cone inside a larger cone, like one sees in traps used nowadays to catch house flies, but this inner cone was useless because the *Simulium* flies dropped back through the opening in the top of it when I tried to take them from the outer cone.

Now *Simulium* flies are stuborn creatures to handle, for the reason that frequently they seem unaffected by light stimuli, at least will remain in a darkened chamber instead of coming into the lighter one. It frequently took an hour to get a few flies to go from a cone in a trap, darkened by covering it with a double thickness of black cloth, into a lighter chamber. The flies were more active and much more easily handled in the early morning while it was cool than later in the day after the temperature had risen. The heat of the day seemed to make them sluggish and inactive, so much so that it was extremely difficult to induce them to go from one cage to another at midday. Again in the evening, when the heat of the day had subsided, they became more active. Literature refers to them as being a cool-weather fly, as most offensive with their biting in the early morning and on cool days. Other places they are spoken of as not biting in warm weather during the summer.

When *Simulium* flies move they generally go very quickly and fly with a great deal of force. At first we removed them from a trap into a glass bottle, but they flew against the transparent sides of the bottle with such force that it seemed to stun them. Their antennæ are comparatively large and protrude forward, so that, in flying against the glass, their antennæ, which are probably their sense organs of touch and perhaps of sound and smell, received a shock that seemed to make the flies more stupid. We then tried taking them into a gauntlet-shaped wire cage covered with cheese cloth. In this they had more room and softer walls to butt their antennæ against. Here they were more quiet and more easily handled.

Plate XXXVIII, figure 3, shows the method of taking them out of a trap into a bottle, except that we placed a black cloth around the cone to darken it at that time. We substituted the gauntlet cage for the bottle. In this manner, when the pupæ were numerous, we were enabled to secure plenty of flies for our experiments.

ECONOMIC IMPORTANCE OF SIMULIUM.

Considerable literature has been written on the depredations of "black flies," "buffalo gnats," "turkey gnats," and "sand flies" (*Simulium*) since the latter part of the eighteenth century, in Europe, and since the pioneer days of settlement in the Mississippi river valley of America. Theobold (British

Flies, vol. I, p. 165) says: "In England we do not suffer much from these flies, but in other parts of Europe they are very obnoxious; Schonbauer (Gesch. der Shadl. Kolumbatezermucken, Wien, 1895; and Kollar's 'Treatise on Injurious Insects,' p. 68) gives an account of one, *S. columbaschensis*, which is one of the greatest scourges to man and beast in the Bannat of Temeswar, in Hungary. Fries (Observ. Entom. [*Simulium*], Stockh., 1824; Fries) also describes the molestations of these 'sand flies' in Lapland."

In America accounts have been written from time to time on the ravages of the different species of *Simulium*. The black fly of the North (*S. molestum* Harris) has been described by Dr. A. S. Packard (Amer. Nat., vol. II, pp. 589-590) as even more formidable a pest than the mosquito, that in the northern subarctic regions it opposes a barrier against travel. "The Labrador fisherman spends his summer on the seashore, scarcely daring to penetrate the interior on account of the swarms of these flies."[4]

The southern buffalo gnat (*S. pecuarum* Riley) and the turkey gnat (*S. meridionale* Riley), in the lower Mississippi valley and tributary regions, and the western buffalo gnat (*S. occidentale* Townsend), along the valley of the Rio Grande, have been the cause of a great deal of suffering to humans by their bites, and the loss of hundreds of head of live stock, including poultry. Accounts of these conditions are given by Dr. C. V. Riley in the Year Book for 1886, U. S. Dept. Agri., Div. Ent., pp. 492-517; in Bul. No. 5, 1896, pp. 31-58; in later publications by O. A. Johannsen, 1903, N. Y. St. Mus. Bul. 68, Ent. 18, Aquatic Insects in N. Y. State; and by Dr. S. A. Forbes, State Entomologist of Illinois, 1912, "On Black Flies and Buffalo Gnats (*Simulium*) as Possible Carriers of Pellagra in Illinois."

Simulium flies, *S. reptans* in particular, have been accused of transmitting the human disease pellagra, by Dr. L. W. Sambon. Doctor Sambon formulated the tsetse fly theory of sleeping sickness, which has proved true. In 1910 he was detailed for three months in Italy, where he studied pellagra. He says, in a brief report on the investigations of pellagra: "The many analogies existing between the epidemiology of pellagra and

4. Insects Affecting Domestic Animals, U. S. Dept. Agr., Div. of Ent. Bul., No. 5, n. s., p. 40.

that the best-known insect-borne diseases; the constant association of the disease with *Simulium*-infested streams; the absence of any other arthropod with similar distribution that might account for it; the striking correlation between the fly and the disease in wide geographical distribution, peculiar topographical exigencies, are all facts which strongly point to *Simulium* as the necessary carriers of pellagra."[5]

Further elucidation of this theory is reviewed by Prof. S. J. Hunter in a paper, The Sand Fly and Pellagra, presented before the Entomological Branch of the American Association for Advancement of Science, Washington, D. C., December 27, 1911, and published in The Journal of the American Medical Association, February 24, 1912, vol. 8, pp. 547-548. A part of this review is as follows:

"A. The endemic centers of pellagra in Italy have remained the same since the disease was first described."

"B. The season of the recurrence of pellagra coincides with the season of the appearance of the full-fledged sand fly, even to the extent that if the spring is early or late, the sand fly is early or late in appearing, and pellagra cases are correspondingly early or late in their appearance."

"C. In centers of pellagra infection whole families are attacked at times simultaneously."

"D. In nonpellagrous districts the disease never spreads to others with the advent of a pellagrin from a pellagrous district."

"E. In the case of a family which has removed from a pellagrous to a nonpellagrous district, the children born in the former district are pellagrins, while the children born subsequent to removal to a nonpellagrous district do not develop the disease."

"F. The disease is not hereditary, although infants a few months old may become infected, especially if taken to the fields in pellagrous districts, where their mothers work during the season when sand flies are in evidence."

"G. Pellagra is not contagious, but is transmitted to each individual by an infected sand fly."

Doctor Sambon found three species of *Simulium* in Italy, *S. reptans*, *S. ornatum*, and *S. pubescens*, chiefly the last. In the United States *S. reptans* has not been discovered, but the Kansas State Board of Health, through the State University and its department of entomology, has carried on investigations as to the presence of *Simulium* flies in localities where pellagrins live, and with the most common species, *S. vittatum*,

5. L. W. Sambon (Journ. Trop. Med. and Hyg., London, 13, 1910, Nos. 18, pp. 271-282, 19, pp. 287-300; 20, pp. 305-315; 21, pp. 319-321). Progress report of the investigation of pellagra, as given in U. S. Dept. Agri. Experiment Station Record, vol. 26, abstract No. 8.

has made experiments to transmit pellagra to a monkey, by first letting the flies bite a pellagrin and then bite a monkey. The full significance of the relation of *Simulium* to the transmission of pellagra has not yet been determined.

MOUTH PARTS OF SIMULIUM VITTATUM.

The question of determining the mouth parts of *S. vittatum* I have attempted to answer, both by their location or place of attachment and by their function as given for the mouth parts of insects in general, and especially those of Diptera, by Dimmock, Kræpelin, Packard, Meinert, and J. H. Smith.

Mandibles.

Packard says: "Mandibles are wanting in the imago male Diptera and the females of all flies except Culicidæ and Tabanidæ."[6]

In "The Skeleton of the Head of Insects," by Comstock and Chujiro Kochi, it says, "To this part," the clypeus, "one condyle (the ventral) of the mandible articulates." Now there is such an attachment as this in *Simulium* mouth parts, as is shown in plate XXXIX, figure 21, plate XLI, figure 28, female, and plate XLI, figure 29, for the male. This forms an exception to Packard's statement quoted above. In *Simulium* the mandible has a basal piece similar to the stipes of the maxilla. (Pl. XL, fig. 22c.) The serrate edge of the mandible has about thirty-two saw-like teeth on its end and sides.

Labrum and Hypopharynx.

The next part in question is the presence of a labrum. Kræpelin says: "The labrum (oberlippe) appears as the direct continuation forward of the upper anterior margin of the basi-proboscis. It has a groove on its under surface, and is in fact an inverted semicylinder with double walls."[7] Packard quotes Meinert as follows: "The hypopharynx, most generally free, more or less produced, acute anteriorly, forms with the labrum the tube of the pump (antliæ)."[8]

A careful dissection of *S. vittatum* mouth parts shows that the part Smith called rods of the mandibles (pl. XXXIX, fig. 23, *L*, and pl. XLI, fig. 28) is the labrum, and that it is connected at its base with the hypopharynx. Plate XXXIX,

6. Packard, A. S., A Text Book of Entomology, p. 62.

7. Kræpelin's Proboscis of Musca.

8. Packard, A. S., A Text Book of Entomology, p. 78.

figure 23, *AB*, shows its attachment and plate XLI, figure 27, its place of attachment after the labrum has been removed. In making this dissection for plate XLI, figure 28, I was unable to tear the hypopharynx away from the labrum without destroying the composite arrangement of the other parts. To keep the parts intact I turned the hypopharynx under and backward. The end of it shows in the upper part of the figure. The muscular attachments of the labrum are shown in dotted outline in plate XL, figure 14, composite view. Since the appendage which I have called the labrum does unite with the hypopharynx to form the opening of the pharynx, and since Kræpelin states that "the so-called epipharynx has no existence,"[7] and that the labrum has a lower wall which was once deemed a distinct piece, the epipharynx, I am persuaded that this appendage is the labrum. Those two chitinized points that Smith has called mandibles are closely connected to the end of the labrum, but not muscularly attached. (Pl. XL, fig. 16.) Their origin is conjectural.

The parts of the labrum *A* and *B*, plate XL, figure 24, are attached at their bases to the base of the hypopharynx at A′ and B′, plate XL, figure 24. That part of the labrum *C*, plate XL, figure 24, seems to be of a muscular nature, or tendonous. It is firmly attached to the clypeus, so firmly, in fact, that I have been unable to tear it loose without tearing to pieces the clypeus. (See plate XL, figure 14.) Furthermore, it seems to be free and unattached except at its ends.

Maxillæ of the "First Maxillæ."

According to Packard, the first maxillæ are inserted in the sides of the head just behind the mandibles and mouth. The three basal pieces supporting the maxillæ, the cardo, stipes, and palpifer, in the order given, may be distinguished as shown in plate XL, figure 17, *cs, PF*. "The three distal divisions of the maxillæ are called, respectively, beginning with the innermost, the lacina, galea, and palpifer, the latter being a lobe or segment bearing the palpus."[9]

From our dissections these parts are found to be present in the order given, and bearing a like description of typical segments of the same, except the galea, which is wanting. The lacina is attached inside the palpifer to the stipes. The palpifer bears a palpus and is also connected to the stipes. (Pl. XL, fig. 17, *PE, PA*.)

9. Packard, A. S., A Text Book of Ent., pp. 62, 63.

A further description by Packard is as follows: "The lacina is more or less jaw-like and armed on the inner edge with either flexible or stiff bristles, spines or teeth." (Pl. XL, fig. 15.) In *S. vittatum* the lacina is produced into a piercing organ with an arrow-like end, with about 26 barb-like formations turned backward on its upper side, and it appears to have a like set on the lower side. These two piercing organs (the lacinæ and mandibles) together with the nub-like chitinized points on the end of the labrum, are evidently used to scrape and tear away the skin in biting. The reason sand flies or buffalo gnats are so tenacious about holding when they are sucking blood may be due to the barbed ends of the lacina caught in the wound. The palpi are four-jointed, the first joint being irregular in shape but about the same length as the second and third joints. The fourth joint is more slender than the second or third and is about two and one-half times the length of one of them. From plate XLI, figure 28, they can be seen to be sparsely covered with setæ.

"Second Maxillæ," or Labium.

Plate XLI, figure 30, shows the so-called second maxillæ, labium or under lip removed. It will be noticed the palpi are wanting. It shows the other typical divisions of a labium, the mentum, glossa, and paraglossa. The labium in *S. vittatum* serves as a sheath for the other mouth parts. This is shown in plate XLI, figure 26, and plate XL, figure 14, composite. It is situated in front of the gula or gular region and is bounded on each side by the gena. See Packard, A Textbook of Entomology, p. 68.

Clypeus.

Plate XL, figure 14*c*, shows the clypeus of the female *Simulium*. According to Packard, the clypeus "is that part of the head situated in front of the epicranium, and anterior to the eyes, forming the roof of the posterior part of the mouth." This describes the position and location of that part of the head of *Simulium* I have called the clypeus. Plate XLI, figure 29, shows a part of the clypeus of a male *Simulium vittatum*. It is smaller and less developed, as are all the mouth parts of the males in comparison to those of the females. Plate XL, figures 20, *c*, 21, and plate XLI, figure 28, show the torn clypeus of the female.

After arriving at the above conclusions in naming the mouth parts of *S. vittatum* my attention was called to a paper by W. Wesche,[10] which describes and figures the mouth parts of *S. reptans* L. The parts he has figured in plate IV of his paper are the maxilla with its palpus and palpifer, the mandible, the labrum with its two minute teeth, the hypopharynx, and the labium. He classes Simulidæ in a group of Diptera in which all mouth parts are distinguishable except the labial palpi, which are aborted. I felt very much gratified at finding his paper to corroborate my conclusions.

The descriptions of the female and male of *Simulium vittatum*, the list of North American species of the family Simuliidæ, and the key to the species of *Simulium* larvæ, pupæ and imagines given below are taken from O. A. Johannsen's work in the New York State Museum Bulletin 68, Aquatic Insects in New York State.

S. vittatum Zetterstedt.

Ins. Lapponica (1844), p. 803.

(*S. tribulatum* Lugger.)

According to Coquillett, *decorum* Walk. (1848) and *argus* Will. (1893) are synonyms.

FEMALE. Gray; nearly bare; dorsum of thorax with five black stripes, the median one entire, the intermediate pairs interrupted, the exterior pair spot-like. Each segment of the abdomen with a dorsal stripe and basally on each side with a black spot, the penultimate segment black. Wings whitish hyaline; halteres white; legs fuscous black, the front side of anterior tibiæ, the base of the middle and hind tibiæ, and the base of the middle and hind metatarsi white. Length 3 mm. Zetterstedt.

FEMALE. The abdomen grey, bases of segments 3 to 7 or 8 marked with a velvet-black fascia produced backward in the middle and at the ends. Length 2 to 4 mm. New York, Minnesota, Nebraska, Kansas, California.

MALE. Hind tarsi bicolorous, mesonotum gray on sides and hind margin, center largely velvet black; without gray streak extending inward from humerus; sides of the abdominal segments 4 to 7 with silvery white hairs. Coquillett.[11]

The markings of the female of this species seem somewhat variable. The thoracic markings are usually quite distinct. The median stripe is nearly of uniform width excepting at the posterior end, where it becomes narrower; the intermediate stripes are f-shaped, the extremities larger, the intermediate

10. Wesche, W., The Mouth Parts of the Nemocera and their Relation to the other Families in Diptera; Journal of the Royal Microscopical Society, pp. 28-47, 1904, published in London.

11. Bul. 10, m. s. 1898, p. 63.

portion usually a hair line, sometimes obsolete; the exterior pair usually elongated spots. The abdominal markings are as described by Coquillett, though occasionally there are additional disconnected, velvet-black lateral spots, one on each side on segments 3, 4, and 7, and a pair on 5 and 6. Sometimes, also, owing either to the contracted condition of the abdomen or to the fasciæ being narrow, only the black projections of the fasciæ are visible on the more posterior segments, giving the appearance of three spots on each. The legs are often gray; the femora and tibiæ paler at the base, the tibiæ black at tip, the tarsi deep black except basal portion of middle and hind metatarsi. Fore tibiæ with one spur, middle and hind with a pair. Tarsal claws of female simple.

Some specimens from Brookings, S. D., received from Professor Aldrich, and which are the males of *vittatum*, possess the following characters:

MALE: Velvety black, antennæ and palpi dark brown; dorsum of thorax velvety black with the anterior and lateral margins narrowly, and posterior margins in front of scutellum widely silvery gray; also two narrow longitudial gray stripes on dorsum. Or the dorsum might have been described as silvery gray with three very wide velvety-black longitudinal stripes, abbreviated behind. Pleura black, bare; scutellum velvety black; metanotum silvery gray; abdomen velvet-black, the sides of first two or three segments of the ventral surface with a silvery reflection in some lights; legs black, the tips of the fore femora, the basal half of fore and hind tibiæ (sometimes the middle one also), the basal two-thirds of hind metatarsi, and the extreme base of the second hind tarsal joint, yellow. Fore tibiæ with a single spur, middle and hind tibiæ with each two; tarsal claws tridentate. Halteres bright orange-yellow. Wings hyaline, the vein yellow. Length 3 mm.

In an article by Lugger, it is stated that in *S. tribulatum* the male is much smaller than the female, having very large, brilliant, red eyes that meet on top of the head; the body is velvety black with bright golden-yellow and blue spots; the female is gray with black markings. This species is said to be the most abundant in Minnesota, where it is called the "black fly." No further description is given; the figures of the male and female agree with the description of *S. vittatum*. Some specimens sent by Mr. Washburn of the Minnesota Experiment Station, labeled *S. tribulatum*, which were sent to me by Professor Needham, he having obtained them from Mr. J. C. Bradley, of Philadelphia:

LARVA (of *S. vittatum*). Somewhat mottled gray, the side of each segment blackish. The larvæ and pupæ were collected by Mr. J. C.

Bradley, Philadelphia, 1901. The head is of the usual reddish-brown color; the pale yellow antennæ long and cylindric, the second joint about one-third the length the first; the third is a pointed process at the tip of the second. The fans have about forty rays, the cilia being relatively minute. The mandibles are provided with three large apical teeth besides the row of secondary ones; the apical pair of bristles are present. The maxillary palpus has a few spines, and a tuft of a few spines on the basal joint. Hypopharynx and labrum apparently like those of other species. The labium has an elongated middle tooth, those at the end nearly as long, the intermediate ones short (pl. 35, fig. 2), and there are six bristles in each of the two longitudinal rows on the ventral surface. The three blood gills at caudal end are unbranched.

PUPA. The thoracic respiratory filaments each consist of a single main trunk, from which arise eight branches, each of which divides into two, thus making sixteen twigs in all (pl. 35, fig. 1). Near the basal margin of the last two abdominal segments are a few caudal-projecting dorsal hooks and on the tip of the last segment is a pair of blunt spines. The pupal case is of the wall-pocket type, from which the respiratory filaments of the pupa project. Judging from the number of respiratory filaments of the pupa, the species described by Osten Sacken in American Entomologist, volume 2, seems to belong here.

LIST OF THE NORTH AMERICAN SPECIES OF SIMULIIDÆ, GENUS SIMULIUM.

Latreille, Hist. Nat. Crust. Ins. (1804), 14:294.

**argus* Williston, N. Am. Fauna, No. 7, May, 1893, p. 253. Cal. (Syn. of *S. vittatum* Zett., according to Coquillett, Harriman Exp. 1900, p. 393.)

argyropeza. See *reptans.*

**bracteatum* Coquillett, U. S. Dept. Agri. Div. Ent. Bul. 10, n. s. 1898, p. 69. Mass., Cal., N. Y., Kan., Mich.

calceatum Harris. A catalogue name, according to Riley, Am. Ent. 1870, p. 467.

cincta. See *reptans.*

**cinereum* Bellardi, Saggio di ditterologia Messicana, 1:13. Cal. (Townsend, Baja, etc., 1893), Mex. (Bellardi).

columbachensis Fabricius nec. Schönhauer. See *reptans.*

decorum Walker. List of Dipterous Insects, etc., ptl., 1848, p. 112. Hudson Bay Ter. (Syn. of *S. vittatum* Zetterstedt, according to Coquillett, n. s., Bul. 10, 1898, p. 68.)

elegans. See *reptans.*

erythrocephala. See *reptans.*

**fulvum* Coquillett, U. S. Nat. Museum Proc. 1902, 25:96.
1898 *ochraceum* Coq. not Walk. Mont., Id., Col., N. M., Alaska.

**glacum* Coquillett, U. S. Nat. Museum Proc., 1902, 25:97. Missouri.

**griseum* Coquillett, U. S. Dept. Agric. Div. Ent. Bul. 10, n. s. 1898, p. 69. Col.

NOTE.—Those names marked * I consider either a distinct species, or not sufficiently described to warrant placing as the synonym of another.

**hirtipes* Fries, Obs. Entomol. Pars, Monogr. Simuliar, 1824, p. 17, 5. Tfl. 1, f. 1. N. Y., Id., Cal. The following synonymy is according to Schiner:

1830 *rufipes* Meigen, Syst. Beschr., 6:311-17.
1830 *hirtipes* Fries, Meigen, Syst. Bescher, 6:312-18.
1850 *hirtipes* Fries, Zetterstedt, Dipt. Scand., 9:3426-28.

innoxium Comstock. See *S. pictipes* Hagen.

**invenustum* Walker, List of Dipterous Insects, etc., 1848, p. 112. Hudson Bay Ter. (*pecuarum* Riley is a synonym of this, according to Coquillett, 1898).

**irritatum* Lugger. Figured but not described in Univ. Minn. Agric. Sta. Bul. 1896, p. 203.

**meriodionale* Riley, Dept. Agric. An. Rep't for 1886, 1887, p. 512. 1891. *occidentale* Townsend, Psyche, July, 1891, p. 107. Mass., Miss., Neb., Tex. (synonym and localities according to Coquillett, Bull. 10, n. s. 1898). N. J. (Johnson) Kan. and Id.

**metallicum* Bellardi, Saggio di ditterologia Messicana, 1859, 1:14. Mex.

**mexicanum* Bellardi, Saggio di ditterologia Messicana, Appendix 6, 1862. Mex.

minutum Lugger, Minn. Agric. Exp. Sta. Bul. 1896, p. 202. Minn. (Figured but not described.) See *vittatum.*

molestum Harris. See *venustum.*

novicum Harris, Ins. Inj. to Veg. p. 601. This is a *Ceratopogon.*

occidentale Townsend. See *meriodionale.*

**ochraceum* Walker, Ent. Soc. London. Trans. n. s. 3:33. Mex.

**pecuarum* Riley (synonym of *invenustum*, according to Coquillett).

1887 *pecuarum* Riley, U. S. Dept. Agric. Rep't for 1886, p. 512. N. H., N. Y., Mass., Ct., D. C., Mich., Miss., La. (synonym and localities according to Coquillett, U. S. Dept. Agric. Bul. 10, n. s. 1898). N. J. (Johnson).

**pictipes* Hagen, Bost. Soc. Nat. Hist. Proc. 1880, 20:305. N. Y., Tex., Cal. (Coquillett, 1898), Id.

1895 *innoxium* Comstock. Name given in Manual for the Study of Insects.

piscicidium Riley. See *venustum.*

posticata Meigen. See *reptans.*

**pulchrum* Philippi, Chilian Diptera, 1865, p. 633. S. Am. and St. Vincent, W. I.

1896 *tarsale* Williston, Diptera of St. Vincent, W. I., p. 268. Synonymy according to Hunter, Catalogue of S. Am. Diptera. 1900.

**quadrivittatum* Loew, Berl. Ent. Zeit. 1862, Centur. 2, p. 2. Cuba.

**reptans* Linnæus, Fauna Suec. 1893. Europe, Greenland (Lundbeck, 1898) 1761. Synonymy according to Schiner:

1767 *sericea* Linnæus, Syst. Nat., 12:978, 58.
1776 *erythrocephala* DeGeer, Ins., 6:161, 37 (Tipula).
1781 *reptans* L. Schrank, Enum. Ins. Austr., p. 985 (Culex).
1787 *colombatchensis* Fabricius, Mantissa Ins. 2:333 (Rhagio).
1804 *argyropeza* Meigen, Classif., 1:96.

1818 *reptans* Meigen, Syst. Beschr., 1:291-92.
1818 *sericea* Meigen, Syst. Beschr., 1:296-98.
1818 *elegans* Meigen, Syst. Beschr., 1:296-99.
1818 *variegata* Meigen, Syst. Beschr., 1:292-93.
1823 *reptans* Fries, Obs. Entomol. Pars. 1 Monogr. Simuliar, p. 13.
1830 *cincta* Meigen, Syst. Beschr., 6:311, 14.
1838 *posticata* Meigen, Syst. Beschr., 7:52, 21.

rufipes Meigen. See *hirtipes.*

sericea Linnæus. See *reptans.*

**tamaulipense* Townsend, N. Y. Ent. Soc. Jour. 1898, v. 7. Tex.

tarsale Williston. See *pulchrum* Phillipi.

tribulatum Lugger, Minn. Agric. Exp. Sta. Rep't 1896, p. 205-7. Probably equals *vittatum* (p. 385, Seq.) (Figured but not described.)

**venustum* Say, Acad. Nat. Sci. Phil. Jour., 3:28: Compl. Wr. 2:51 Wiedemann, Auss. zw. Ins., 1:71. Ohio, D. C. (Osten Sacken, catalogue), N. J. (Johnson), Can., N. H., N. Y., Mich., Minn., Wyo., B. C., Cal., Tex., La., Miss., Fla. (Coquillett), Id. The following synonymy is according to Coquillett, 1898:
1862 *molestum* Harris, Ins. Inj. to Vegetation. (Not described.)
1870 *piscicidium* Riley, Am. Ent. 2:367. Mumford, N. Y.

**virgatum* Coquillett, U. S. Nat. Mus. Proc. 1902, 25:97. N. M.

**vittatum* Zetterstedt, Ins. Lapponica. 1840. p. 803.

stæger Grœnl. Antl. Greenland (Osten Sacken's catalogue), N. J. (Johnson), Alas. (Coquillett 1900), Cal., Kan., Minn., N. Y., Neb. (Coquillett 1898), Id., S. Dak. The following synonymy according to Coquillett:
1848 *decorum* Walker, List. Ins. p. 112. Hudson Bay Ter.
1893 *argus* Williston, N. Am. Fauna, No. 7, p. 253. Cal.

KEY TO SPECIES OF SIMULIUM.

Larvæ.

1. Mature larva of 6 or 7 mm. long, with the dorsal surface of the head nearly white; the rays of the fan number about 30. Larva from Santa Cruz mountains, Cal. (p. 387).
   Head usually brown; rays of the fan usually 40 or more 2
2. The top of the head with six black blotches or spots. Larvæ from New Mexico (p. 386).
   Head without six dark spots 3
3. The Caudal blood gills are three simple papillæ 4
   The three main branches are again subdivided 6
4. The middle tooth of the labium is simple and pointed, labium with six pairs of setæ on its ventral surface (pl. 35, fig. 8).
   Pecuarum (*-invenustum*)
6. Full-grown larvæ 10-12 mm. in length, black in color, its labium with an elongate middle tooth (pl. 36, fig. 3) ..... *pictipes*
   Paler larvæ less than 10 mm. in length 7

7. No setæ on the last joint of the maxillary palpus, middle tooth of the labium longer than the two lateral ones, four pairs of setæ on its ventral surface. The pair of apical setæ of the mandible not differentiated from the hairs which overhang the apex. *meribionale*

Mandible with a pair of apical bristles, palpus of the maxilla with setæ 8

8. Middle tooth of the labium enlarged, ventral surface of labium with five pairs of setæ (pl. 37, fig. 6) ..... *venustum*

Middle tooth not enlarged (varieties of *venustum*) 9

9. Labium with four pairs of ventral setæ (pl. 37, fig. 14) .... var. *a*

With seven pairs of setæ (fig. 5) ..... var. *piscicidium*

PUPÆ.

(Arranged according to the number of filaments in each respiratory tuft.)

1. With six filaments:
   a. Legs in their cases appear bicolored * ..... *venustum*
   b. Legs unicolored ..... *meridionale*
2. With eight filaments:
   a. Pupa 4.5 mm. long; Arizona species. Pupa described in Am. Ent. Soc. Trans., p. 45; 1893.
   b. Less than 4 mm. long; eastern species. *venustum*, var. *piscicidium*
3. With nine filaments. Pupal case like that on plate 35, figure 5. *pictipes*
4. With ten filaments ..... var *a* of *venustum*
5. With twelve filaments. Pupal case (pl. 35, fig. 5). From Santa Cruz mountains, California (p. 387).
6. With sixteen filaments ..... *vittatum*
7. With twenty-four to forty-eight filaments (pl. 33, fig. 10). *pecuarum*
8. With sixty or more filaments ..... *hirtipes*

IMAGINES.

1. Ground color of the thorax and abdomen deep yellow 2

Gray or black; its hairs may be pale 3

2. "Femora with black tip, length of fly 2 mm." Mexico... *ochraceum*

"Femora with black tips. Length 3 to 4.5 mm. Rocky Mountains." *fulvum*

3. Hind tarsi with its basal joint partly yellow; legs bicolored 9

Hind tarsi unicolored † 4

4. Halteres dusky; thorax not striped 5

Halteres white or yellow; the female with striped thorax and bifid tarsal claws 6

* In order to see this it will be necessary to examine nearly mature specimens, and perhaps to draw them from their pupal skins.

† The male of the *pictipes* sometimes has legs nearly unicolored; it is, however, included in the preceding section.

5. Body black; the female with dense yellow pile, her tarsal claws simple; the male with dense hair on the legs, his tarsal claws trifid. The wing with its radius three branched. Length 3 to 4.5 mm. ..... *hirtipes*

"Body gray, legs reddish gray, feet black; length 3 mm." This is said by Mr. Coquillet to be the same as *pecuarum* Riley. *invenustum*

6. Males, eyes contiguous 7

Females, eyes separated by a distinct line 8

7. Thorax velvety black; legs reddish with black tarsi. Length 1.5 to 2 mm. Compare here also *bracteatum* (male), "with legs wholly brown" ..... *meridionale*

Thorax brownish black; legs usually pale; tip of tarsi not black. Length from 2 to 4 mm. ..... *pecuarum*

8. Thorax with silvery-white pubesence; legs brownish black, covered with whitish hairs. A small variety (less than 2 mm. long) from New Mexico has been named *occidentale* Town. (q. v.) *meriodionale*

Thorax with yellow hairs; legs reddish brown, covered with yellow hairs; tip of tarsi blackish ..... *pecuarum*

9. Male, eyes contiguous 10

Females, eyes separated 20

10. "Mesonotum wholly velvet black; gray spot on sides of the second, fifth, sixth, and seventh segments of abdomen. Length 1.5 mm." *bracteatum*

Metanotum striped, or with grayish or metallic reflections 11

11. Dorsum of thorax with one or more longitudinal stripes 12

Dorsum unstriped 14

12. Thorax with four longitudinal stripes; posterior margin white; abdomen black. Sex not given. Cuban species.. *quadrivittatum*

Thorax not so marked 13

13. Front and middle femora and tibiæ wholly yellow; center of mesonotum with a black vitta, elsewhere gray. Length 1.5 mm. Colorado species ..... *griseum*

Femora and tibiæ wholly or partly brown 13*a*

13*a*. "Femora and front tibæ yellow, their apices brown, middle tibiæ brown, a yellow ring beyond the base, hind tibiæ brown, the extreme base yellowish. Mesonotum marked with a narrow median and laterally with a very broad velvet-black fascia." Length 3 mm. New Mexico ..... *virgatum*

Front femora brown, tibiæ brown on apical part 13*b*

13*b*. Mesonotum with two narrow gray stripes (sometimes quite indistinct) on a velvet-black ground, in which there are scattered golden hairs ..... *vittatum*

"Mesonotum marked with a narrow median and slightly wider lateral black vittæ." Length 2.5 mm. Missouri..... *glaucum*

14. Anterior femora yellow. Mexican species 15

Anterior femora black 17

—

15. Abdomen with the base of the second segment and the sides of the third, fourth, and fifth yellowish white; tibiæ fuscous black with yellow bases. Length 4 mm. ..... *mexicanum*

Abdomen black 16

16. Metallic bluish black species; middle portion of fore tibiæ, base of middle and hind tibiæ, base of first and second joints of middle and hind tarsi, whitish. Length 2 mm. ..... *metallicum*

Thorax fuscous and cinereous pollinose; the humeri pallid, fore coxæ pale, middle and hind ones dark; femora pale at the base, black at the tip; tibiæ black. Length 3 mm. ..... *cinereum*

17. An oblique metallic streak extending inward from each humerus; posterior part of the thorax metallic. Length 2 to 2.5 mm. *venustum*

Humeral spots not metallic 18

18. Anterior coxæ yellow; long hair on femora and hind tibiæ; thorax velvet black with white pruinose margin (Greenland) .. *reptans*

Anterior coxæ black 19

19. Thorax velvet black, with oblique cinereous humeral spots, and usually two tiny metallic spots between them. Length 3 to 4 mm. *pictipes*

Thorax velvety black with two very narrow gray stripes and posterior margin; hind tibiæ usually yellow at the base, hair on legs sparse ..... *vittatum*

20. Thorax striped 21

Thorax without stripes 25

21. Dorsum of thorax with four longitudinal lines, posterior margin, white pollinose; abdomen opaque black. Cuban species. *quadrivittatum*

Not with four stripes 22

22. Dorsum of the thorax with five stripes, the outer ones spot-like, the intermediate ones clubbed at the ends; abdomen with black fascia on each segment, produced posteriorly at the middle and the ends. Sometimes the last few segments have only three or five spots ..... *vittatum*

Toe with one or three stripes 23

23. With three stripes 24

"With an indication of a darker median vitta" (see 31) .. *griseum*

24. Small species, length about 1.5 mm. "Abdomen silvery, third and fourth segments wholly brownish, sometimes with a median spot on each; legs yellowish, tarsi blackish or brownish." Species from Texas ..... *tamaulipense*

Larger species 3 mm. or more in length 24*a*

24*a*. Middle tibiæ brown with a yellow ring around the base; vittæ of mesonotum brownish, the median vitta dilated posteriorly, wider than either of the lateral ones. New Mexico ..... *virgatum*

Femora and tibiæ grayish, sometimes quite pale, tips of tibiæ black. Laterdorsal thoracic stripes clubbed at the anterior end. Third, fourth, fifth, and part of the sixth and seventh abdominal segments with velvet-black fasciæ; center of 6, 7, 8, grayish or dull brown ..... *pictipes*

25. Abdomen without distinct black spots 26
Abdomen spotted 31
26. Abdomen black, covered with long yellow pile, legs yellow, the tips of the femora and tibiæ, and all the tarsi except basal two-thirds of the hind metatarsi, brown ..... *bracteatum*
Abdomen nearly bare 27
27. Body gray or cinereous 28
Body brown or black 29
28. "Body gray with a milky white lustre, specially the pleura and pectus. Legs tawny, femora and tibiæ with irregular piceous bands, tarsi piceous. Length 2.5 mm. Hudson Bay Ter." This is a synonym of *vittatum* Zett., according to Mr. Coquillet (1898). *decorum*

Thorax fuscous or cinereous pollinose, humeri pallid, pleura pale cinereous, scutellum pale at the tip; abdomen blackish; fore coxæ pale, middle and hind ones cinereous; femora pale at the base, black at the tip, tibiæ black. Length 3 mm. Mexican species ..... *cinereum*
29. Abdomen somewhat shinning, yellowish gray or whitish at the sides, and yellow at the base; legs brown, tibiæ and fore coxæ white, tip of tibiæ and all tarsi black. European species, also occurring in Greenland ..... *reptans*
Basal segments of abdomen opaque, distal four segments somewhat shining black or brown. Two long hairs at the tip of the first and third fore tarsal joints 30
30. Legs reddish yellow, tarsi black, except proximal half of middle and hind metatarsi which are light yellow. Length 2 mm. (St. Vincent Island.) This is a synonym of *pulchrum* Phil., according to Hunter ..... *tarsale*
Legs black; base of tibiæ, first joint of middle and hind tarsi and sometimes base of femora yellow; extensor surface of all the tibiæ more or less whitish. A widely distributed and variable species ..... *venustum*
31. Length 1.5 mm. Front and middle femora and tibiæ wholly yellow; hind ones, except apices, also yellow. (Colorado) ..... *griseum*
Length 2.5 mm. Legs, brownish black, distal part of femora, base of tibia, and greater part of metatarsi light yellow (California). *argus*

Some of the characters used in this table have been taken from the key given in the United States Department of Agriculture, Division of Entomology, Bulletin 10, new series, 1898, page 68, by Mr. Coquillet. In the table given above I have included all the North American species. For the southwestern and Mexican species it should, however, be used with caution, as I did not have specimens of some of these.

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